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Direct Current Electric Arc-Electroslag Ladle Furnace

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Abstract: In order to solve the high consumption problem of small capacity ladle furnace (LF), the operation principle and control method of the DC arc and electroslag heating ladle furnace are introduced. With only one arcing electrode, the distance between the arc and the wall of ladle is enlarged, and consequently the consumption of the ladle refractory is decreased. In the invention, a signal electrode is embedded in the refractory lining of the ladle, which contacts directly with the liquid steel and the ladle shell. Two graphite anode ends are submerged in the slag layer. The signal electrode is used as voltage reference during refining process. The electroslag voltage between anode end and liquid steel is applied to control the depth of anode end in the slag layer during the refining process with this ladle furnace.

Key words: ladle furnace; secondary refining; DC; electroslag

1 Problem of Secondary Metallurgy Furnace with Small Capacity

Most of steelmaking furnaces in China are of smaller capacities, 15–40 t. The pitch circle of smaller AC ladle furnaces is usually lager than 550 mm. In these cases, the consumption of refractory material of ladle wall is very high due to the "outer flow " effect (arc deflection), and the refining cost is increased. Putting 3 electrodes in one electrode arm can make pitch circle smaller, but smaller distance between 2 electrodes will cause arcing under higher operational voltage. On the other hand, if the operational voltage is limited, the heating speed will be limited, the heating time and the consumption of power and graphite electrode will increase.

In recent years, with the development of direct current EAF (electric arc furnace), direct current ladle furnace has been developed both at home and abroad [1, 2]. In order to solve the problem of high consumption of refractory for small capacity LF, a new type of ladle furnace with 3 top electrodes but only one arc is developed by University of Science and Technology Beijing, Anyang Iron and Steel (Group) Co. Ltd., and Anshan Research Institute of Heat Energy.

2 Principal of Direct Current Electric Arc-electroslag Ladle Furnace

The system configuration of direct current electric arc-electroslag ladle furnace (DCEASLF) is shown in **figure 1**, two outer graphite electrodes (anode) are positioned in the slag layer with certain distance to liquid metal pool by a special control system. A voltage U_{ES} is maintained between metallic bath and each anode end which enables slag heating by electric current. An electric arc with a voltage U_{ARC} produced under the center graphite electrode (cathode) realizes the heating of metallic bath.

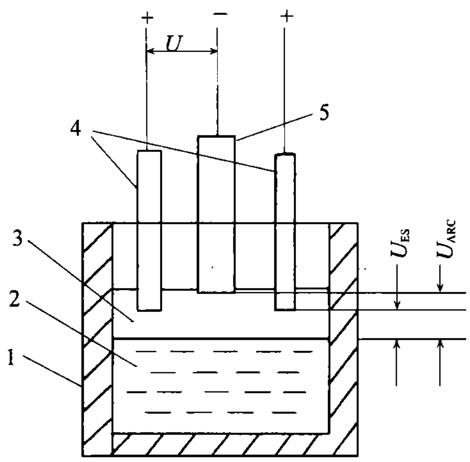

Figure 1 Principle diagram of DCEAELF, 1—ladle; 2—liquid steel; 3—liquid slag; 4—graphite anode; 5—graphite cathode.

The following equations describe the relationship among the electric parameters of the system.

$U = U_{ARC} + U_{ES}$,

$I_{ARC} = I_{ES1} + I_{ES2}$,

$P = U_{ARC} I_{ARC} + U_{ES} (I_{ES1} + I_{ES2})$.

Where U is the load voltage; U_{ARC} the arc voltage; U_{ES} the electroslag voltage; I_{ARC} the cathode current; I_{ES1} the anode 1 current; I_{ES2} the anode 2 current; P the heating power.

Comparing with the existing DC ladle furnace, DCEAELF has the following advantages:

(1) A special control system is applied to maintain a certain distance between the anode ends and the metallic bath, and therefore the voltage U_{ES} is controlled. In above case, as the anodes contact with the molten metal, the carbon pickup of liquid steel can be prevented and the electroslag heating in the two zones beneath the two anodes can be realized. By adjusting U_{ES} the electroslag heating ratio can be adjusted.

(2) In the same energy load condition, the arc voltage will be lower and beneficial for submerged arc operation.

(3) The electroslag process improves the kinetic reaction condition between metal and slag, especially the desulphurization efficiency is raised.

3 Computer Control System of DCEAESLF

3.1 Configuration of Computer Control System

The computer control system of DCEAESLF consists of 2 levels, process computer (level 2) and basic automaton computer (level 1). Process computer consists of an industrial microcomputer IPC610, industrial keyboard, a 20"high-resolution color monitor and a printer. Level 1 consists of a series of modules of programmable controller with high reliability and high interference resistance. The configuration of computer control system is shown in **figure 2**.

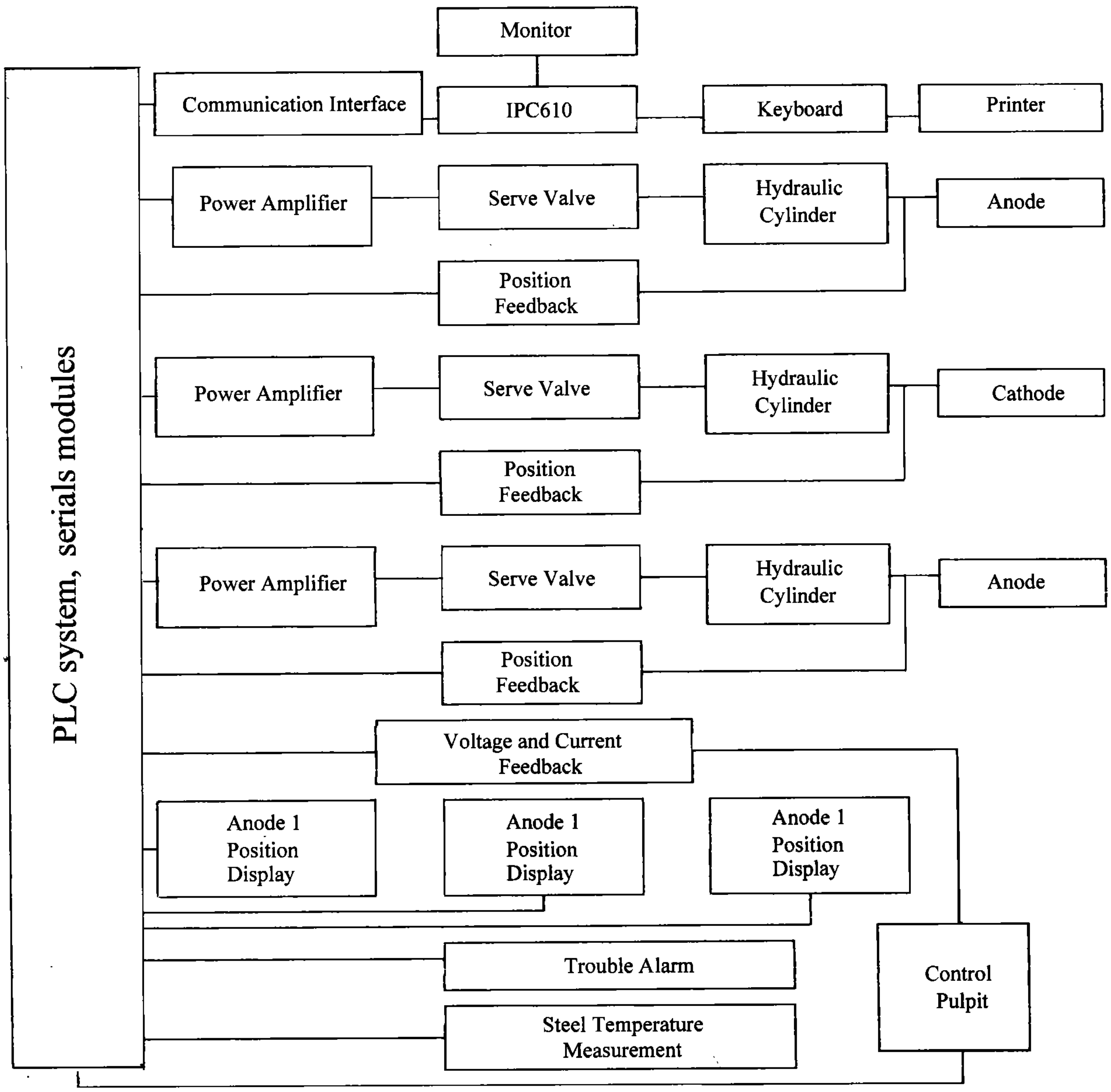

Figure 2 Computer control diagram of DCEAESLF.

3.2 Functions of computer control system

(1) Main functions of process computer.

The main functions of the process computer are specified as follows:

1) Computing of mathematical model of heat balance and on line direction of operation;

2) Displaying technological and control parameters, alarm signal and trends of parameters on the monitor in real time via man machine interface (MMI) facilities;

3) Setting and modifying values of control parameters of refining process;

4) Collecting of production data, storing original data, and printing data report.

(2) Main functions of basic automation computer.

The main functions of basic automation computer include:

1) Automatic anode positioning. No matter how much liquid steel is in the ladle, slag level will be measured accurately and the original anode ends will be positioned exactly in slag layers. During the refining process, the anodes will be controlled not to contact with metallic bath, so that the carbon pickup of liquid steel is avoided effectively.

2) Automatic cathode arc igniting. After the original positions of anodes are determined, the cathode will go down and ignites the arc automatically.

3) Controlling constant slag resistance. During the refining process, according to the given anode voltage, the position of each anode in the slag layer is regulated, the voltage drop in slag layer is kept within a stipulated range and the constant slag resistance control is realized.

Moreover, there are functions of cathode current controlling, anode voltage controlling, electrode position controlling, trouble alarming and technology and control parameters collecting.

3.3 Features of system

(1) During the refining process, the signal electrode gives a stable and reliable reference point for measuring arc voltage of cathode and resistance voltage of anode. So reliable control parameters are given for refining process control. The proprietary method of acquiring voltage signal enables good controllability of cathode voltage and anode voltage in the refining process.

(2) Accurate measurement and reliable control of the computer system enable a stable and reliable cathode arc igniting.

(3) With feedback signal of electrode position, the electrode position is closed-loop controlled by the system. Detected signal of position can quickly and accurately posited the electrode and the operation time is then shortened. The real time display of electrode position shows the situation in the ladle clearly at a glance.

4 Operation of DCEAESLF

The following economic and technical results are achieved within more than 72 months operation of the 25 t DCEAESLF with 4 000 kVA in Anyang Iron and Steel (Group) Co. Ltd.:

(1) Tap to tap time of EAF is shortened by 20 min;

(2) Average heating speed is higher than 3 ℃/min, the maximum 5 ℃/min;

(3) Electrode consumption speed during heating time is <0.02 kg/(min·t);

(4) Power consumption of heating is 1.2 kW·h/(℃·t);

(5) On condition that all heats are refined with DCEAESLF continuously, the life of ladle refractory is longer than 40 heats;

(6) Without applying special refining technology, total amount of inclusion is 49×10^{-6}, total oxygen is 29×10^{-6};

(7) Regarding the costs of raw material, power, labor and the depreciation of equipment, the cost of EAF+LF is increased by 18.41 ¥/t compared with single EAF process.

It is clearly shown that DCEAESLF can meet the requirements for improving the steel quality, reducing the cost, ensuring the flexibility in the production.

5 Conclusions

(1) A new type of refining equipment - DCEAESLF has been developed.

(2) A proprietary control system is applied, the ends of graphite anodes are kept in the slag layer with a required voltage to the metallic bath, and electroslag heating is realized.

(3) Significant results have achieved by DCEAESLF in EAF process.

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